Three-dimensional computer modeling of realistic marine CSEM earth models in the Flemish Pass Basin

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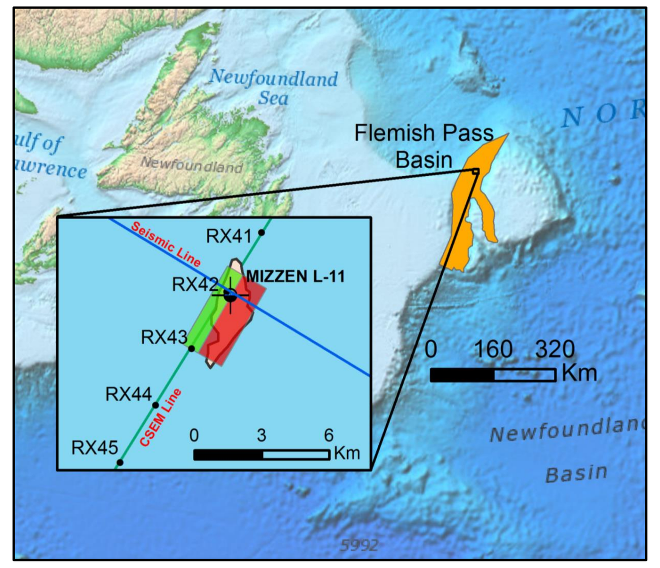
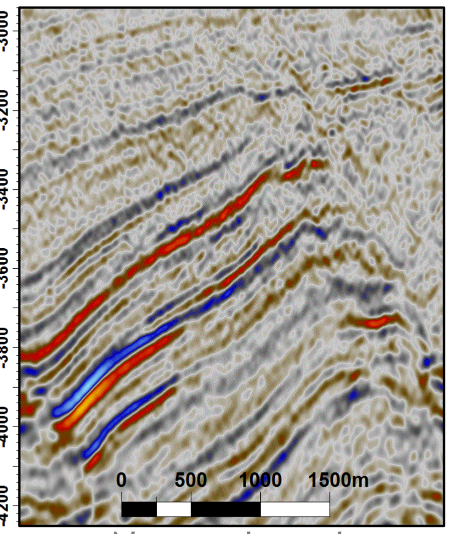
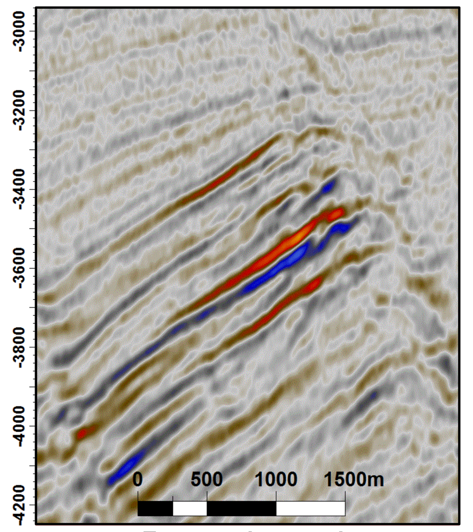
Introduction

- 2D seismic data acquired in the Flemish Pass Basin shows AVO anomalies in three Tithonian aged sands up-dip from where a well, Mizzen L-11, was drilled
- As an alternative approach to fluid substitution, our method uses 3D marine CSEM forward modelling software (Ansari and Farquharson, 2014) on unstructured meshes to assess the potential in these sands
- Finite-element (FE) algorithms on unstructured meshes allow for local refinement and can realistically represent subsurface complexities
- This method is used in conjunction with comparisons to mCSEM data acquired by EMGS to assist in de-risking a reservoir in a real offshore exploration setting





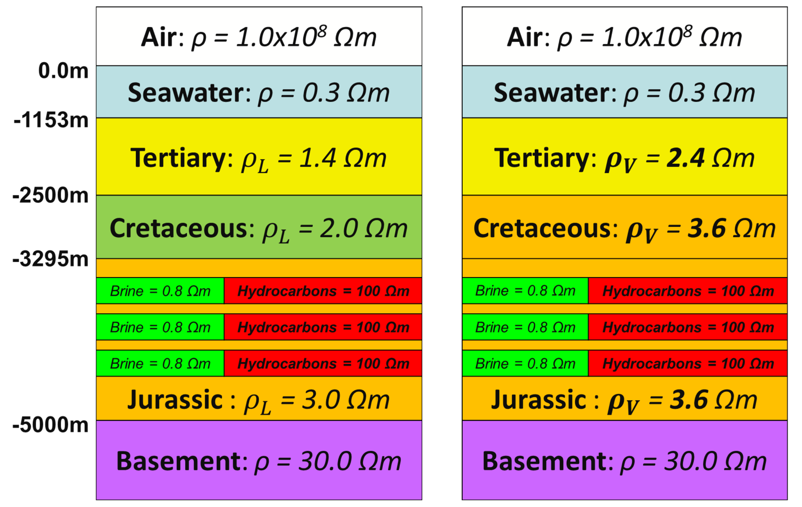
Near angle stack

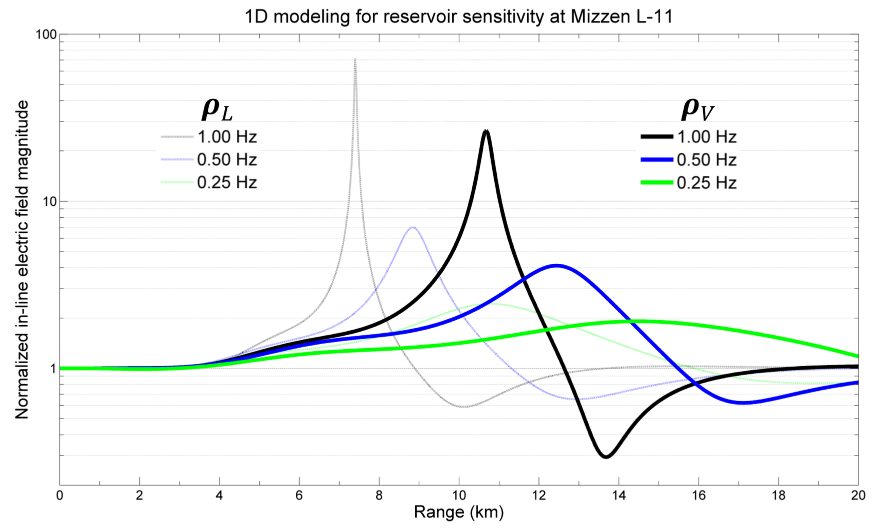


Far angle stack

1D sensitivity modeling

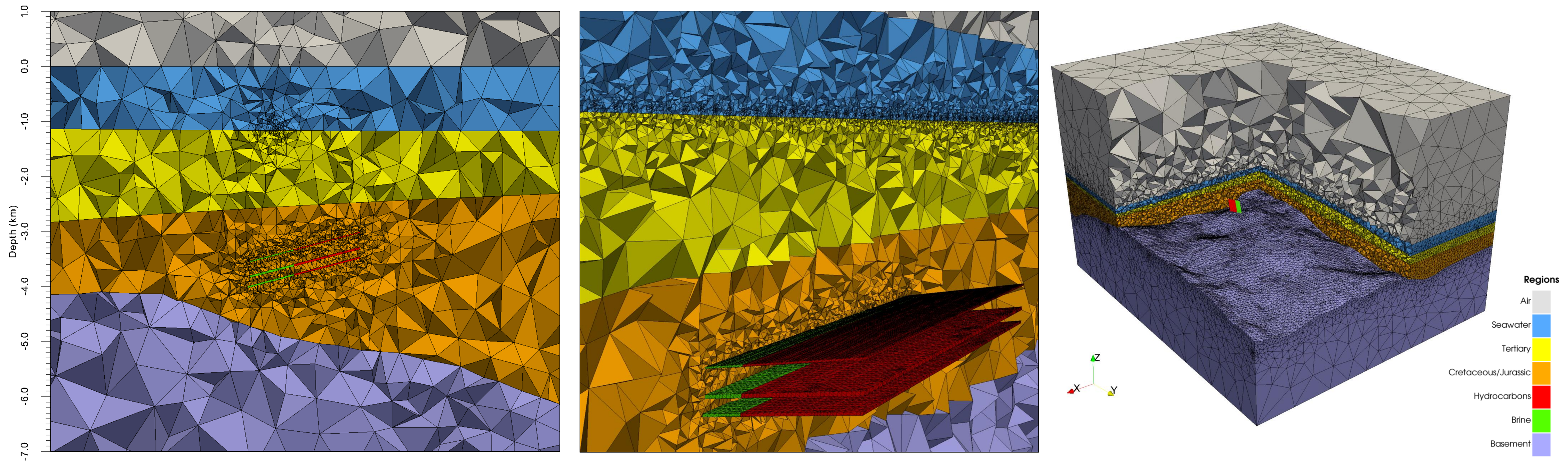
- The sensitivity of marine CSEM to buried resistors depends on their burial depth, lateral extent, and transverse resistance (Constable, 2010)
- An approximate method to determine sensitivity to the L-11 reservoirs is through 1D modelling, which was achieved using DIPOLE1D (Key, 2009)
- The blocked resistivities from the L-11 well log are representative of ρ_L (*left table*), but in-line mCSEM fields are most sensitive to ρ_V (*right table*)
- The sensitivities shown are calculated by normalizing the hydrocarbon to the brine sand responses for both ρ_L and ρ_V





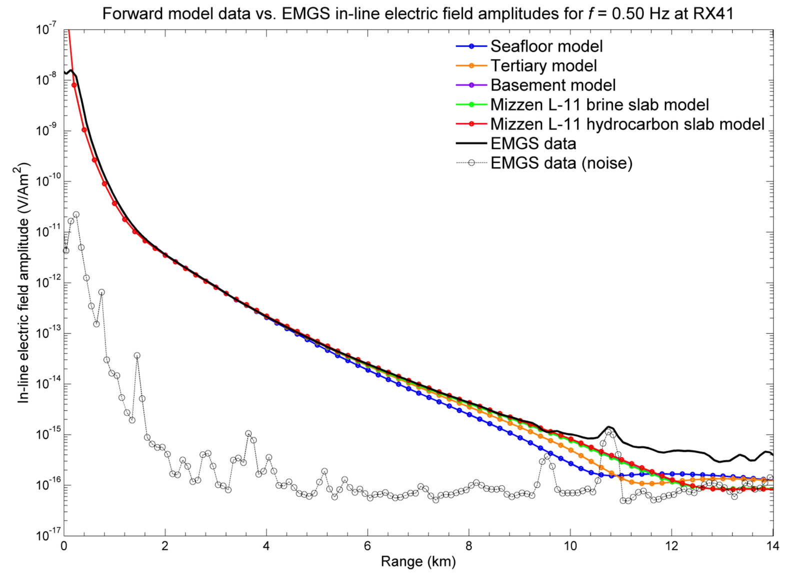
3D model building

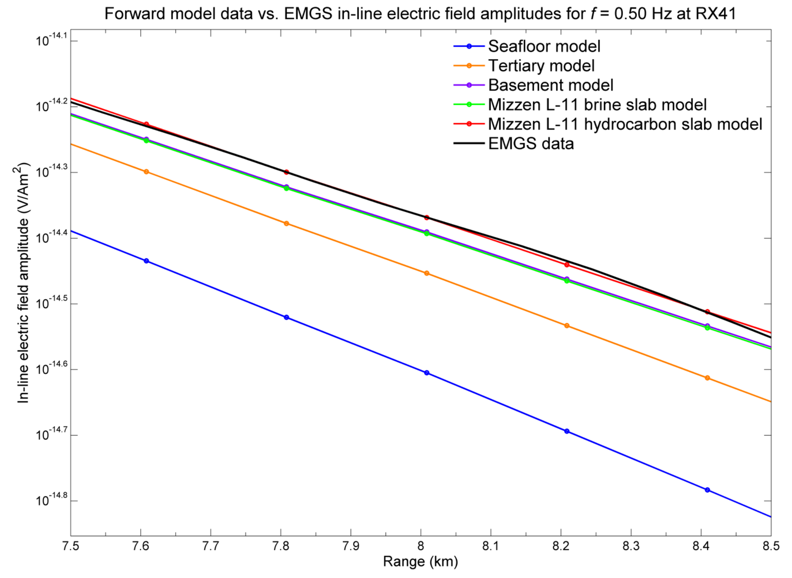
- The 3D models were built using (1) three surfaces separating geochronologic intervals defined by 2D seismic lines to delineate subsurface structure, (2) the L-11 well-log to assign resistivities to each region, (3) and seismic AVO data and public information to determine the extent of the sands
- The L-11 sands were approximated as dipping slabs with the up-dip portion containing hydrocarbons
- Hydrocarbon portions of the slabs were roughly calculated to have ≈40M barrels of recoverable oil
- Slice along the seismic line (*left panel*), perspective view along the mCSEM survey line (*middle panel*), 3D perspective view of the 50 x 60 x 40 km computational mesh (*right panel*)

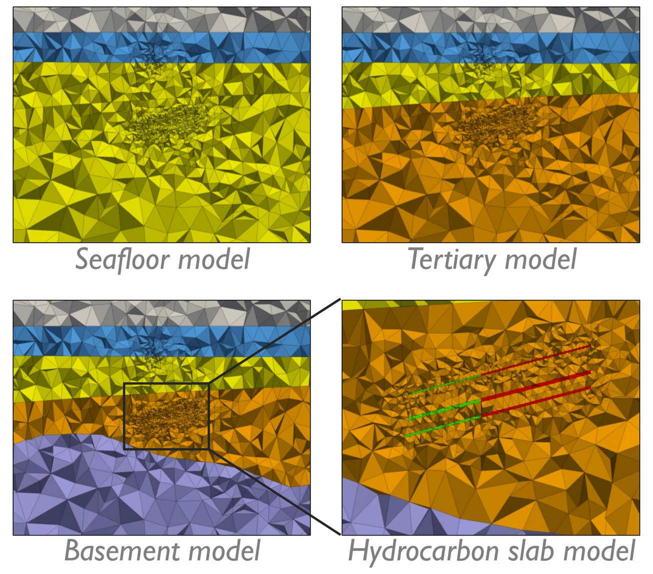


Numerical results

- Surfaces were incrementally added to the model with an iterative process of making simulations at each step, making comparisons to the measured EMGS data, and updating ρ_V as needed
- Numerical simulations were generated at three different frequencies (0.25 Hz, 0.50 Hz, and 1.00 Hz) and at five receivers surrounding the L-11 prospect (*see onset map*)
- For all of the results generated, the recovered amplitudes were of good quality, the iterative solver converged well, and the reservoir responses matched well with the measured data
- The brine response curve assumes the up-dip portions of the sands are also filled with brine

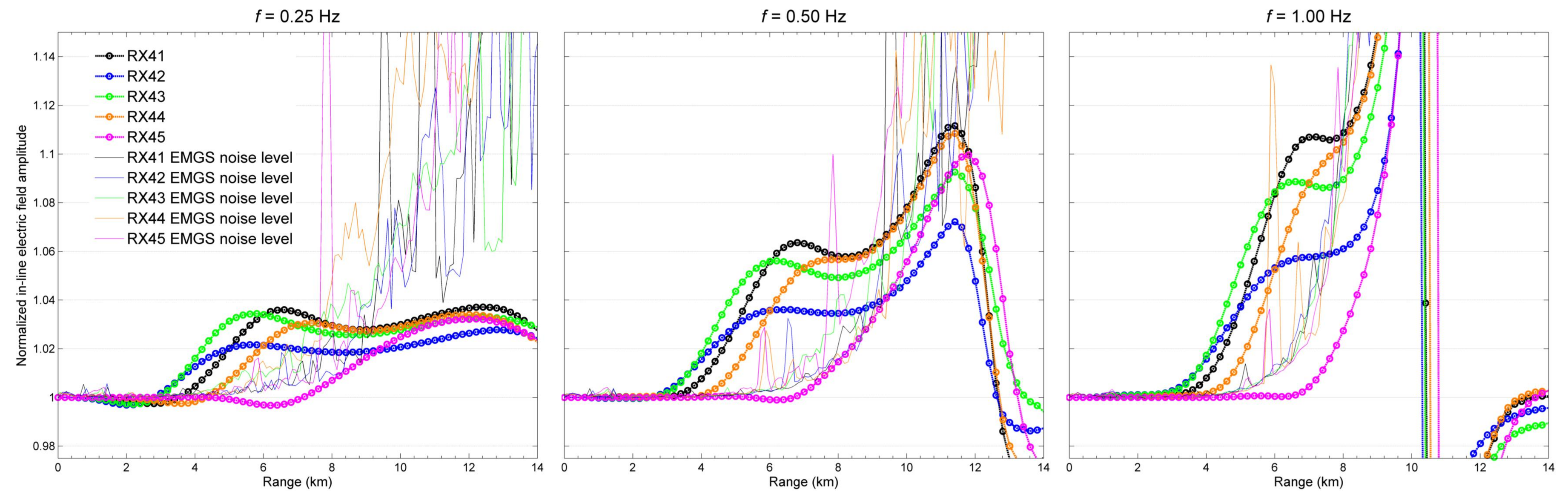





Seafloor model
Tertiary model
Basement model
Hydrocarbon slab model

Interpretation

- Sensitivity analysis is used to evaluate the detectability of the L-11 sands
- All hydrocarbon responses were normalized to brine responses
- The noise was normalized by the in-line amplitude to quantify the noise contribution to the measured EMGS data for each receiver and frequency
- A small sensitivity does exist, but the maximum sensitivity for all receivers/frequencies occurs at an offset dominated by noise in the data



Conclusion

- Was able to construct models of realistic scale and complexity despite the data limitations of the Flemish Pass Basin being in an exploration phase
- The L-11 reservoir appears to be borderline detectable, and the lack of a strong sensitivity thereof translates to mCSEM struggling to distinguish between brine and hydrocarbon saturations for this reservoir in particular
- However, in the range of 4 - 8 km there appears to be a sensitivity that lies above the noise threshold for the frequencies considered and these multiple pieces of data could stack in an inversion to give a small anomaly
- The L-11 reservoir is small, but further testing has shown if the reservoir was larger, 3D mCSEM would be far more sensitive and serve as a useful supplement

References & Acknowledgements

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